Appendix A – Budgetary Information

The schedule for achieving the targets and R&D priorities outlined in this plan is based on expected funding levels, the current stage of development of different technologies, and the perceived difficulty in attaining the targets. Deviation from the expected funding levels may alter the schedule for completion of the tasks and milestones. For example, if funding falls short of expected levels, the target dates for completion of certain milestones may be extended to later dates. If additional funding is made available over the expected amount, the rate of technology development could be accelerated in key research areas.

Funding Profile:

The funding profile for the Hydrogen, Fuel Cells & Infrastructure Technologies Program is shown in Table A.1. Consistent with the National Energy Policy there has been a steady increase in funding from FY2001 through FY2003. The President's Hydrogen Fuel Initiative of $1.2 billion over 5 years is reflected in the FY2004 request. In order to reach its targets, the Hydrogen, Fuel Cells & Infrastructure Technologies Program expects funding to maintain the level that has been projected within internal DOE planning documents. If funding deviates from these projections, priorities have been established to reallocate funds.

Table A.1. Fiscal Year Funding (2002-2004)

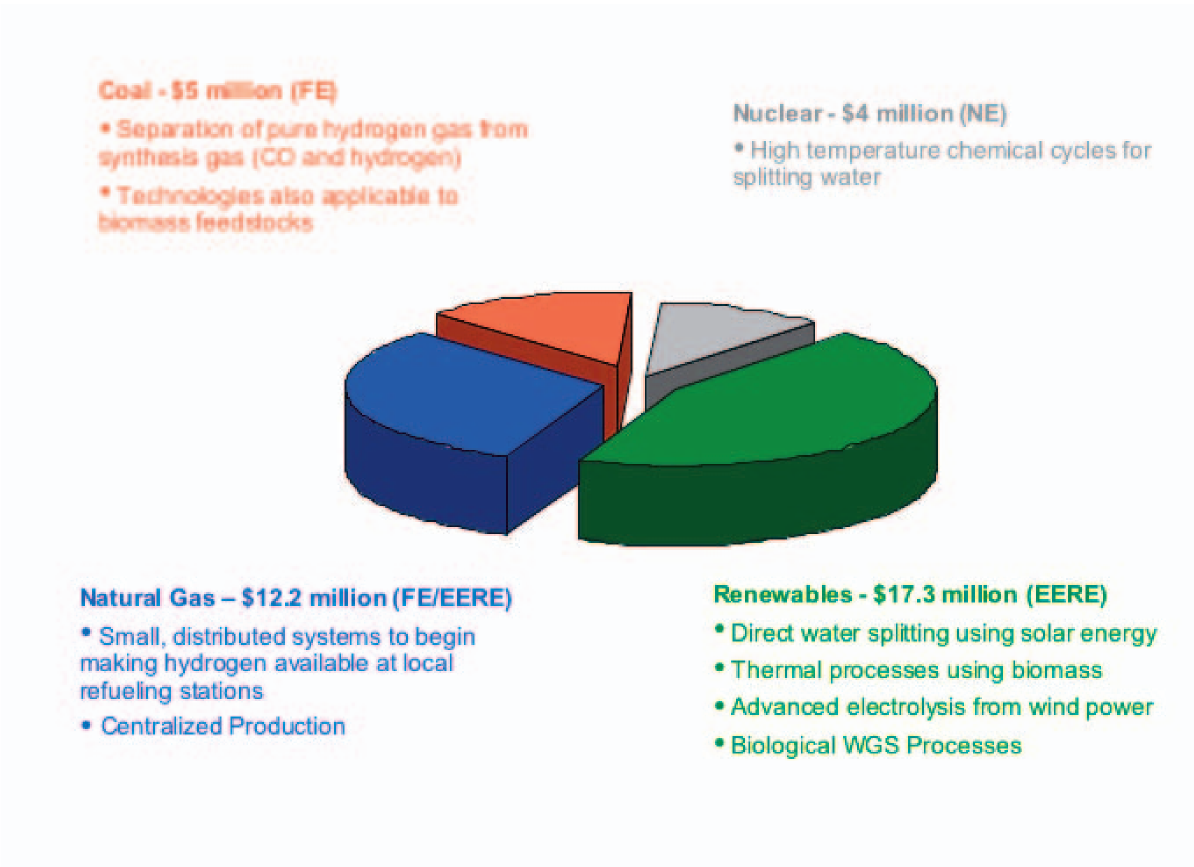
Major Activities	FY02 Approp.	FY03 Approp.	FY04 Request
Hydrogen Technology			
Hydrogen Production & Delivery	$11.2M	$11.8M	$23.0M
Hydrogen Storage	$6.1M	$11.3M	$30.0M
Safety, Codes & Standards, Utilization	$4.5M	$4.8M	$16.0M
Education and Cross-Cutting Analyses	$1.4M	$2.0M	$5.8M
Infrastructure Validation[a]	$5.7M	$10.1M	$13.2M
Subtotal, Hydrogen Technology	**$28.9M**	**$40.0M**	**$88.0M**
Fuel Cell Technology			
Transportation Systems	$7.5M	$6.2M	$7.6M
Distributed Energy Systems	$5.5M	$7.5M	$7.5M
Stack Component R&D	$12.6M	$14.9M	$28.0M
Fuel Processor R&D	$20.9M	$24.7M	$19.0M
Technology Validation[a]	0	$1.8M	$15.0M
Technical Support	$0.2M	0.4M	0.4M
Subtotal, Fuel Cell Technology	**$46.7M**	**$55.5M**	**$77.5M**
TOTAL, Hydrogen and Fuel Cells	**$75.6M**	**$95.5M**	**$165.5M**

a - The Infrastructure Validation and Technology Validation line items are covered under the HFCIT Program's "Technology Validation" activity

Hydrogen Production Funding:

The Department of Energy's Offices of Fossil Energy; Nuclear Energy, Science and Technology; and Energy Efficiency and Renewable Energy are collaborating on cost-shared hydrogen production R&D. The planned FY2004 breakdown of this arrangement can be seen in Figure A.1.

Figure A.1. Hydrogen Production Funding within DOE



Appendix B – Milestones

Table B.1. Hydrogen Production Milestones

Task	Milestone	Milestone description	Date (FY) Q = quarter
Distributed Reforming			
1	1	Downselect feedstocks for distributed hydrogen production.	2Q, 2005
2, 18	2	Input from Safety: Safety requirements and protocols for refueling	2Q, 2004
2	3	Output to Technology Validation: Hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $3.00/kg hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.	3Q, 2004
2	4	Complete pilot-scale testing of hydrogen membrane reactor DFMA methods.	4Q, 2004
2	5	Input from Fuel Cells: Fuel-flexible fuel processor technology	1Q, 2005
3	6	Output to Technology Validation: Hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $2.50/kg hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.	4Q, 2007
3	7	Output to Technology Validation: Hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $1.50/kg hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.	4Q, 2010
Central Production Technologies from Fossil Fuels and Biomass			
4	8	Select membrane system for oxygen/air separations.	4Q, 2007
4	9	Select improved, impurity-tolerant reforming catalysts.	4Q, 2009
4	10	Demonstrate pilot-scale integrated oxygen membrane/gasification reactor.	4Q, 2009
5	11	Verify at pilot scale (100 kg H_2 per day) technologies to reduce the cost of biomass pyrolysis, with operational efficiency improvements to include reduced coking and improved feeding mechanisms.	4Q, 2008
6	12	Select biomass gasification technologies for development based on potential to reduce biomass-to-hydrogen cost.	4Q, 2005
6	13	Complete development and testing of pilot-scale biomass gasification technologies.	4Q, 2008
7	14	Select cost-effective hot gas clean up technology.	4Q, 2006
7	15	Verify cost-effective gasifier product gas clean up.	4Q, 2008

8	16	Select reforming reactor technologies for development.	4Q, 2005
8	17	Output to Technology Validation: Hydrogen production system making hydrogen for $2.60/kg from biomass at the plant gate	IQ, 2008
8	18	Verify advanced catalysts and reactor configuration for fluid-bed reforming of biomass pyrolysis liquid at pilot scale (500 kg H_2 per day), with catalyst attrition rates less than 0.01% per hour.	4Q, 2009
8	19	Verify technologies for catalyst improvement for reforming of biomass gasifier producer gases at pilot scale (500 kg H_2 per day), with LHV conversion efficiencies of 89%.	4Q, 2009
8	20	Complete development and testing of high-efficiency, advanced biomass reformer reactor technologies.	4Q, 2009
8	21	Verify biomass-based production of hydrogen at projected plant gate cost of $2.60/kg.	4Q, 2010
9	22	Select pathways for improving conventional water-gas-shift catalysts and reactors, including single stage shift, for further research.	4Q, 2004
9	23	Complete design and testing of bench-scale membrane reactor to carry out shift conversion and hydrogen separation.	4Q, 2005
9, 10, 11	24	Verify cost-effective hydrogen separation membranes with a flux rate of 100 scfh/ft^2 for $150/ft^2.	4Q, 2006
9	25	Select advanced shift catalysts that are more efficient and impurity tolerant.	4Q, 2007
9	26	Verify engineering scale (100-L empty-bed reactor volume) bioreactor that performs the water-gas-shift reaction.	4Q, 2009
10, 11	27	Verify hydrogen purification technology that reduces the cost of hydrogen separation and purification by 30% compared to today's PSA technology.	4Q, 2010
Tasks Specific to Biomass Technologies			
12	28	Select fermentation technologies to be developed for converting renewable biomass resources to hydrogen.	4Q, 2006
12	29	Downselect fermentation technologies for converting renewable biomass resources to hydrogen.	4Q, 2009
Photobiological Technologies			
13, 14	30	Develop a photobiological system with the potential for 10% utilization efficiency of absorbed light energy and 0.5% absorbed light to hydrogen energy efficiency that produces hydrogen (at laboratory scale) continuously for 500 hours at a projected cost of $100/kg.	4Q, 2005
13, 14	31	Demonstrate (at laboratory scale) a photobiological system with 20% utilization efficiency of absorbed light energy and 5% absorbed light to hydrogen energy efficiency that produces hydrogen continuously for 1,500 hours at a projected cost of $30/kg.	4Q, 2010
13, 14		Verify an engineering-scale biological system that produces hydrogen at a plant-gate cost of $10/kg projected to commercial scale.	4Q, 2015

Photolytic Technologies			
15	32	Go/No-Go: Identify materials/systems that could achieve >10% solar-to-hydrogen efficiency, with projected durability of 10,000 hours, with a cost approaching $22/kg.	4Q, 2008
16	33	Verify (at laboratory scale) a photoelectrochemical water-splitting system that could produce hydrogen at a projected cost of $9/kg at the plant gate with technology concepts identified to further reduce these costs.	4Q, 2010
17	34	Select cost-effective transparent hydrogen impermeable material for photolytic production.	1Q, 2009
15, 16		Verify a direct photoelectrochemical water splitting with a plant-gate hydrogen production cost of $5/kg projected to commercial scale.	4Q, 2015
Electrolysis			
18	35	Go/No-Go: Decision on high-temperature steam electrolysis based on a complete technoeconomic analysis and laboratory-scale research results.	4Q, 2005
18	36	Verify $2.00/kg plant gate hydrogen production from centralized electrolysis.	4Q, 2008
18	37	Verify renewable integrated hydrogen production with water electrolysis at a hydrogen cost of $2.50/kg (electrolyzer capital cost of $300/kWe for 250 kg/day at 5,000 psi with 73% system efficiency).	4Q, 2010
High-Temperature Thermochemical Technologies			
19	38	Verify an effective integrated high-temperature chemical-cycle/ water-splitting thermochemical hydrogen production at a pilot scale.	4Q, 2008
19	39	Initiate the design of a demonstration-scale nuclear energy enabled high-temperature chemical-cycle/water-splitting production system that projects to a cost of <$2.00/kg of hydrogen at the plant gate by 2015.	4Q, 2010
20	40	Downselect viable chemical-cycle/water-splitting or other chemical splitting cycles for ultra-high-temperature thermochemical production.	4Q, 2008
20	41	Verify (at small scale) an ultra-high-temperature chemical-cycle/ water splitting or other chemical-splitting cycle that projects to a cost of <$5/kg of hydrogen at the plant gate.	4Q, 2010
9		Go/No-Go: Replace shift reaction in distributed reforming with one-step reaction reformer.	4Q, 2012

Table B.2. Hydrogen Delivery Milestones

Task	Milestone	Description	Date (FY)
1	1	Complete definition of a cost-effective hydrogen fuel delivery infrastructure to support the introduction and long-term use of hydrogen for transportation and stationary power.	4Q, 2005
1	2	Output to Hydrogen Storage: Assessment of cost-competitive off-board storage requirements	4Q, 2005
2	3	Verify 20% cost reduction for hydrogen compression.	4Q, 2008
2, 3, 4, 5, 6	4	Define technology-feasible routes and approaches for hydrogen fuel delivery (gate to refueling unit) for a cost of less than $1/kg.	4Q, 2010
4,5,6	5	Input from Hydrogen Storage: Initial downselect of on-board storage system	4Q, 2007
4,5,6	6	Input from Hydrogen Storage: Final downselect of on-board storage system	4Q, 2009
3	7	Verify 50% cost reduction for hydrogen liquefaction.	4Q, 2010
3	8	Increase the energy efficiency of hydrogen liquefaction from 65% to 87%.	4Q, 2010
4,5,6	9	Input from Safety: Safety requirements and protocols for pipelines and transit	2Q, 2005
4, 5, 6	10	Input from Hydrogen Storage: Bulk off-board storage technology for fueling stations and delivery	2Q, 2007
4	11	Verify reduction of the capital cost of hydrogen pipelines by 50%.	4Q, 2010
5	12	Verify the feasibility of hydrogen carrier systems with 10% hydrogen by weight.	4Q, 2007
5	13	Verify the feasibility of a hydrogen carrier system that could achieve a cost of <$0.70/kg of hydrogen for hydrogen transport distances of 100 miles or less.	4Q, 2010

Table B.3. Hydrogen Storage Milestones

Task	Milestone	Description	Date (FY)
1	1	Complete feasibility study of hybrid tank concepts.	4Q, 2005
1	2	Output to Technology Validation: Compressed and cryogenic liquid storage tanks achieving the 2005 targets	4Q, 2005
1	3	Go/No-Go: Decision on insulated pressure vessels for cryogenic tanks with minimum evaporative losses	4Q, 2006
1	4	Go/No-Go: Decision on liquid and compressed tank technologies	4Q, 2006
2	5	Output to Technology Validation: Advanced compressed/cryogenic tank technologies; End tank R&D	4Q, 2009

3	6	Complete construction of materials test facility.	4Q, 2004
3	7	Complete verification of test facility.	2Q, 2005
3	8	Go/No-Go: Decision point on carbon nanotubes	4Q, 2005
3	9	Complete prototype complex hydride integrated system meeting 2005 targets.	2Q, 2006
3	10	Downselect complex hydride materials.	4Q, 2006
4	11	Output to Technology Validation and Fuel Cells: Complex hydride integrated system meeting 2005 targets	3Q, 2007
4	12	Complete prototype complex hydride integrated system meeting 2010 targets.	4Q, 2008
4	13	Go/No-Go: Decision on continuation of complex hydride R&D	4Q, 2009
4	14	Go/No-Go: Decision point on other carbon nanostructures	4Q, 2009
6	15	Downselect from hydride regeneration processes.	2Q, 2005
6	16	Demonstrate efficient hydride regeneration laboratory process.	2Q, 2006
6	17	Complete chemical hydride life-cycle analysis.	3Q, 2006
6	18	Demonstrate scaled-up hydride regeneration process.	4Q, 2006
6	19	Complete prototype hydride integrated system.	4Q, 2006
6	20	Downselect from chemical storage approaches for 2010 targets.	4Q, 2006
7	21	Output to Technology Validation and Fuel Cells: Full-cycle, integrated chemical hydride system meeting 2005 targets	2Q, 2007
7	22	Demonstrate advanced hydride regeneration laboratory process.	4Q, 2008
7	23	Complete prototype advanced chemical storage integrated system.	2Q, 2009
7	24	Demonstrate scaled-up advanced hydride regeneration process.	4Q, 2009
7	25	Go/No-Go: Decision point on chemical storage R&D for 2015 targets	4Q, 2009
9	26	Downselect from advanced concepts.	4Q, 2006
10	27	Downselect the two most promising advanced concepts for continued development.	4Q, 2009
12	28	Input from Safety: Safety requirements and protocols for on-board storage	2Q, 2004
12	29	Update on-board storage targets.	4Q, 2006
12	30	Complete analysis of best storage option for 2010 targets.	4Q, 2007
12	31	Output to Hydrogen Delivery: Initial downselect of on-board storage system	4Q, 2007
12	32	Complete analysis of best storage option for 2015 targets.	4Q, 2009

12	33	Output to Hydrogen Delivery: Final downselect of on-board storage system	4Q, 2009
13	34	Complete assessment of vehicle interface technology needs for compressed and liquid tanks.	1Q, 2004
13	35	Downselect from “smart tank” technologies.	4Q, 2006
13	36	Output to Technology Validation: Vehicle interface technology	4Q, 2006
14	37	Complete assessment of vehicle interface technology needs for advanced materials storage systems	1Q, 2007
14	38	Downselect vehicle interface technology needs for advanced materials storage systems.	4Q, 2009
14	39	Output to Technology Validation: Vehicle interface technology	4Q, 2009
16	40	Input from Safety: Safety requirements/protocols for bulk storage	2Q, 2004
16	41	Input from Hydrogen Delivery: Assessment of cost-competitive off-board storage requirements	4Q, 2005
16	42	Output to Technology Validation and Hydrogen Delivery: Bulk off-board storage technology for fueling stations and delivery	2Q, 2007
16	43	Go/No-Go: Decision on continued R&D for off-board storage	2Q, 2007

Table B.4. Fuel Cells Milestones

Task	Milestone	Description	Date (FY)
Transportation Systems			
1	1	Complete development and testing of low-cost, high-sensitivity sensors.	1Q, 2006
1	2	Go/No-Go: The status of sensors and controls technologies will be assessed and compared with the established technical and cost targets. Based on the assessment and the degree of success, the technologies will be released for use, more development will be indicated, or effort will be terminated.	1Q, 2006
3	3	Deliver critical analysis of well-to-wheels analyses regarding fuel cell system performance, efficiency, greenhouse gas emissions, and cost .	2Q, 2003
3	4	Deliver model of FCV system.	4Q, 2003
3	5	Quantify fuel cell power systems emissions.	4Q, 2003
3	6	Complete initial evaluation of 75-kW advanced integration, atmospheric gasoline reformed system.	1Q, 2004
3	7	Complete modeling of the availability and economics of platinum group metals.	1Q, 2004
3	8	Complete analysis for overall and specific component costs for transportation fuel cell systems.	1Q, 2005
4	9	Complete development and testing of low-cost, high-efficiency, lubrication-free compressors, expanders, blowers, motors, and motor controllers.	1Q, 2006

4	10	Complete development of heat rejection technologies (compact humidifiers, heat exchangers, and radiators).	1Q, 2006
4	11	Go/No-Go: The status of air management and thermal management technologies will be assessed and compared with the established technical and cost targets. Based on the assessment and the degree of success, the technologies will be released for use, more development will be indicated, or effort will be terminated.	1Q, 2006
4	12	Input from Storage: Complex hydride integrated system meeting 2005 targets	3Q, 2007
Distributed Generation Systems			
6	13	Complete 4,000-hour test of ethanol-fueled distributed generation system.	2Q, 2004
6	14	Demonstrate prototype back up power system.	1Q, 2007
6	15	Demonstrate stationary fuel cell system with 35%-40% electrical efficiency.	3Q, 2007
7	16	Input from Storage: Full-cycle, integrated chemical hydride system meeting 2005 targets	2Q, 2007
7	17	Output to Technology Validation: Stationary PEM Systems with 40,000-hour durability	4Q, 2010
8	18	Verify fuel processing subsystem performance for distributed generation to meet system targets for 2010.	1Q, 2007
9	19	Demonstrate performance (600 mV at 400 mA/cm^2) of an ultra-thin membrane (< 75 μm) in an MEA under atmospheric conditions at 120°C in a 30-cm^2 cell.	3Q, 2003
10	20	Demonstrate the effective utilization of fuel cell thermal energy for heating to meet combined heat and power (CHP) efficiency targets.	1Q, 2008
Fuel Processors			
11	21	Demonstrate fuel-flexible fuel processor meeting year 2005 targets for efficiency, power density, specific power, and emissions. Measure startup capability.	2Q, 2003
11	22	Verify quick-start concept in brass-board prototype system demonstrating capability to meet 2010 startup technical target.	4Q, 2003
11	23	Verify small scale, microchannel reformer.	4Q, 2003
11	24	Fabricate prototype ion transport membrane module.	1Q, 2004
11	25	Go/No-Go: Determine whether to continue advanced fuel processing R&D and downselect technology to meet year 2010 technical targets (80% efficiency, 800 W/L, 800 W/kg, <0.5 min startup)	3Q, 2004
11	26	Output to Production: Fuel-flexible fuel processor technology	1Q, 2005
12	27	Verify low-cost, high-efficiency hydrogen enhancement systems.	4Q, 2005
12	28	Verify quick-start concept in brass-board prototype system demonstrating capability to meet all 2010 technical targets.	1Q, 2007

Components			
13	***29***	Demonstrate 120°C membrane in MEA/single cell.	1Q, 2005
13	***30***	Demonstrate 120°C MEA in <10 kW stack.	1Q, 2006
13	***31***	Go/No-Go: Demonstrate MEA in single cell meeting 2005 platinum loading and performance targets	2Q, 2006
13	***32***	Verify first generation 150°C membrane in MEA/single cell.	1Q, 2007
14	***33***	Verify reproducibility (physical and performance) of full-size bipolar plates in high-rate manufacturing processes.	1Q, 2004
14	***34***	Verify reproducibility (physical and performance) of full-size MEAs in high-rate manufacturing processes.	1Q, 2005
14	***35***	Output to Technology Validation: Laboratory PEM technology with 2,000 hours durability, $125/kW	2Q, 2005
15	***36***	Output to Technology Validation: Laboratory PEM technology with 5,000 hours durability, $45/kW	1Q, 2009
16	***37***	Identify main routes of DMFC performance degradation.	4Q, 2003
16	***38***	Go/No-Go: Determine whether to continue funding of DMFC R&D for transportation applications	4Q, 2003
17	***39***	Downselect design scenarios for vehicular fuel cell APUs for further study.	4Q, 2003
17	***40***	Complete evaluation of fuel cell systems for APUs.	1Q, 2005
17	***41***	Demonstrate 20-50 W portable power fuel cell system at 30 W/kg, 30 W/L, and $5/W.	1Q, 2007
17	***42***	Verify 3-10 kW APU system at 80 W/kg and 80 W/L.	1Q, 2007
17	***43***	Output to Industry: Portable power PEM technology	2Q, 2007

Table B.5. Technology Validation Milestones

Task	Milestone	Description	Date (FY)
1,2,4	***1***	Make awards to start fuel cell vehicle/infrastructure demonstration activity and for hydrogen co-production infrastructure facilities	3Q, 2004
1	***2***	Input from Safety: Safety requirements and protocols for vehicle safety and stationary refueling	1Q, 2005
1	***3***	Input from Fuel Cells: Laboratory PEM technology with 2,000 hours durability, $125/kW	2Q, 2005
1	***4***	Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles.	2Q, 2005

1	5	Input from Storage: Compressed and cryogenic liquid storage tanks achieving the 2005 targets	4Q, 2005
1	6	Validate (on a vehicle) 1.5 kWh/kg and 1.0 kWh/L compressed gas and cryogas tank, with projected cost of $10/kWh.	1Q, 2006
1	7	Validate (on a vehicle) conformable pressurized and cryogenic tanks that increase effective kWh/L by 20% at 1.2 kWh/l and projected cost of $10/kWh.	3Q, 2006
1	8	Go/No-Go: Decision for purchase of additional vehicles based on performance, durability, and cost criteria	4Q, 2006
1	9	Validate fuel cell demonstration vehicle range of ~ 200 miles and durability of ~ 1,000 hours.	4Q, 2006
1	10	Go/No-Go: Decision on reformers	4Q, 2006
1	11	Input from Storage: Vehicle Interface Technology	4Q 2006
1	12	Output to Codes and Standards, Safety, and Education: Final report for first generation vehicles, interim progress report for second generation vehicles on performance, safety, and O&M	1Q, 2007
1	13	Validate (on a vehicle) 2.0 kWh/kg and 1.2 kWh/L compressed gas tank, with projected cost of $10/kWh	1Q, 2007
1	14	Input from Storage: Bulk off-board storage technology for fueling stations and delivery	2Q, 2007
1	15	Input from Storage: Full-cycle, integrated chemical hydride system meeting 2005 targets	2Q, 2007
1	16	Input from Storage: Complex hydride integrated system meeting 2005 targets	3Q, 2007
1	17	Validate reversible complex hydride storage.	4Q, 2008
1	18	Validate vehicle refueling time of 5 minutes or less.	1Q, 2008
1	19	Validate chemical storage on vehicle at 2.0 kWh/L and 2.2 kWh/kg with projected cost of $100/kWh.	2Q, 2008
1	20	Demonstrate FCVs with 300-mile range, 2,000-hour durability, and $125/kW (based on volume production).	1Q, 2009
1	21	Input from Fuel Cells: Laboratory PEM technology with 5,000 hours durability, $45/kW	1Q, 2009
1	22	Input from Storage: Verify advanced compressed/cryogenic tank technologies; End tank R&D	4Q, 2009
1	23	Input from Storage: Vehicle Interface Technology	4Q, 2009
1	24	Output to Codes and Standards, Safety, and Education: Issue final report on vehicle performance, safety, and O&M	3Q, 2010
1	25	Input from Fuel Cells: Stationary PEM Systems with 40,000-hour durability	4Q, 2010
2	26	Input from Production: Verify hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $3.00/kg hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.	3Q, 2004

2	27	Five stations and maintenance facilities constructed with advanced sensor systems and operating procedures.	4Q, 2006
2	28	Total of eight stations and two maintenance facilities constructed with advanced sensor systems and operating procedures.	1Q, 2008
2	29	Issue final report on safety and O&M of refueling stations	1Q, 2009
2	30	Validate maintenance costs for hydrogen FCVs and validate cost of producing hydrogen in quantity of $3.00/kg untaxed.	1Q, 2009
3	31	Validate $3/kg hydrogen cost.	1Q, 2006
3	32	Output to Codes and Standards and Safety: Submit final report on safety and O&M of three refueling stations	4Q, 2007
3	33	Input from Production: Verify hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $2.50/kg hydrogen at the pump, untaxed, no carbon sequestration, assuming 100s of units of production per year.	1Q, 2007
3	34	Validate $2.50/kg hydrogen cost.	3Q, 2008
4	35	Operate prototype for 6 months; projected durability >5,000 hours; electrical energy efficiency >30%; availability >0.80.	1Q, 2007
4	36	Operate first regional networks with fuel cell systems that project <$1,250/kW	1Q, 2008
4	37	Operate second regional networks with fuel cell systems that project <$1,250/kW	1Q, 2009
4	38	Input from Production: Verify hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $1.50/kg hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.	4Q, 2010
4	39	Achieve network fuel cell statistical values of: 30,000-hour durability; electrical energy efficiency >35%; availability >0.80.	1Q, 2011
5	40	Test results from 100,000 scf/day unit with wind turbine, and validation of production cost of $300/kW at 85% efficiency.	1Q, 2007
5	41	Input from Production: Verify hydrogen production system making hydrogen for $2.60/kg from biomass at the plant gate	4Q, 2007
5	42	Input from Production: $500/kW, 80% efficient technology	2Q, 2008
5	43	Validate $3.30/kg hydrogen cost from biomass/wind (untaxed and unpressurized).	3Q, 2010
6	44	Results from analysis of examination of synergies from combining hydrogen and electricity energy carrier systems, including advanced Power Parks.	2Q, 2006

Table X.Y.11. Codes and Standards Milestones

Task	Milestone	Description	Date (FY)
1	1	Produce a curriculum for training modules.	3Q, 2003
1	2	Output to Education: Training modules for current practices	2Q, 2004
1	3	Collaborate with ICC and NFPA to develop first- order continuing education for code officials.	2Q, 2004
1	4	Establish a coordination plan with education sub program to run workshops for state and local officials.	3Q, 2004
1	5	Establish schedule of training for state and local officials.	4Q, 2004
1	6	Output to Education: Training modules for amended practices for new technologies	2Q, 2005
2	7	Develop a mechanism for hydrogen technical experts to support the code development process.	4Q, 2003
2	8	In conjunction with model code developers, draft approach to provide analytical and experimental support for code changes.	4Q, 2004
2	9	Execute analytical experiments and collect data as needed to support code development.	4Q, 2005
3	10	Produce gap analysis for critical standards and determine which standards development organizations (SDOs) should lead efforts.	3Q, 2003
3	11	Initiate negotiations with critical SDOs and develop draft generic licensing agreement and estimate of costs.	4Q, 2003
3	12	Prepare final generic licensing agreement, schedule of critical licensing agreements, and budget requirements for FY04.	1Q, 2004
4	13	Draft standards for transportable containers	1Q, 2004
4	14	Draft standards for refueling stations	3Q, 2004
4	15	Draft standards for vehicles	1Q, 2005
4	16	Draft standards for stationary power	3Q, 2005
4	17	Draft standards for the integration of sensors and leak detection equipment	1Q, 2006
4	18	Finalize standards for transportable containers	1Q, 2006
4	19	Finalize standards for refueling stations	3Q, 2006
4	20	Draft standards for portable fuel cells	4Q, 2006
4	21	Finalize standards for vehicles	1Q, 2007
4	22	Finalize standards for stationary power	3Q, 2007
4	23	Finalize standards for the integration of sensors and leak detection equipment	1Q, 2008
4	24	Finalize standards for portable fuel cells	4Q, 2008

5	25	Negotiate agreement with DOT/NHTSA at Working Party on Pollution and Energy meeting.	3Q, 2003
5	26	Assemble a team of technical experts to support international standards development process.	3Q, 2003
5	27	Develop a mechanism to support appropriate U.S. Technical Advisory Groups (TAG).	3Q, 2003
5	28	Inputs from all program elements: Technology Assessments	2Q, 2005
6	29	Identify areas of joint agreement between EIHP and PATH.	3Q, 2003
6	30	Initiate the development of the next generation Sourcebook to include Japan, Europe, Canada & U.S.	1Q, 2004
6	31	Review and negotiate terms and conditions with necessary parties.	2Q, 2004
7	32	Negotiate terms and conditions for licensing ISO standards.	4Q, 2006
7	33	Obtain general licensing agreement.	4Q, 2007
8	34	Convene workshop to identify and develop critical research objectives that limit or impact model codes.	4Q, 2003
8	35	Produce a research plan including schedule and budget	1Q, 2004
8	36	Develop standards for connector interface	4Q, 2005
8	37	Develop standards for on-board storage	4Q, 2006
8	38	Develop standards for fuel dispensing	4Q, 2007
8	39	Develop standards for crash worthiness (substation)	4Q, 2007
8	40	Finalize standards for crash worthiness (vehicle)	4Q, 2008
9	41	With industry and code officials, develop templates of commercially viable footprints for fueling stations that incorporate underground and aboveground storage of liquid and gaseous hydrogen.	1Q, 2004
9	42	Circulate research plan to stakeholders and incorporate comments.	1Q, 2004
9	43	Publish the Phase 1 research plan.	2Q, 2004
9	44	Issue solicitation for work required in the Phase 1 research plan.	2Q, 2004
9	45	Develop templates of commercially viable footprints for fueling stations that incorporate advanced technologies	1Q, 2007
9	46	Circulate research plan to stakeholders and incorporate comments.	1Q, 2007
9	47	Publish the Phase 2 research plan.	2Q, 2007

9	48	Issue solicitation for work required in the Phase 2 research plan.	2Q, 2007
10	49	Complete the harmonized regulation for hydrogen storage.	4Q, 2004
10	50	Complete the technical draft for vehicular safety standards.	4Q, 2004
10	51	Implement analytical and experimental program to support the submittal of a comprehensive vehicular safety standard as a regulation	4Q, 2005
10	52	Complete standards for fuel cell power plants, for performance verification of efficiency and emissions.	4Q, 2005
10	53	Implement research program to support five new technical committees for the key critical standards including fueling interface, power block, and fuel storage.	4Q, 2006
10	54	Prepare a comprehensive draft regulation for a vehicle to be submitted as a GTR.	4Q, 2008
10	55	Draft regulation approval as a GTR.	4Q, 2009

Table B.7. Safety Milestones

Task	Milestone	Description	Date (FY)
1	1	Review existing data and develop classification systems for assessment.	4Q, 2003
1	2	Develop, in collaboration with NASA, DOT, and DOC, a search protocol on component and system safety.	1Q, 2004
1	3	Develop prioritization methodology.	1Q, 2004
1	4	Output to Storage: Safety requirements and protocols for bulk storage	2Q, 2004
1	5	Output to Storage: Safety requirements and protocols for on-board storage	2Q, 2004
1	6	Complete and distribute the potential accident scenarios for review and agreement.	3Q, 2004
2	7	Draft protocol.	1Q, 2004
2	8	Workshop to review protocol.	1Q, 2004
2	9	Release consensus protocol.	2Q, 2004
2	10	Perform literature search.	4Q, 2004
2	11	Output to Technology Validation: Safety requirements and protocols for vehicle safety and stationary refueling	1Q, 2005
3	12	Assemble panel of experts in hydrogen safety to provide expert technical guidance to funded projects.	4Q, 2003
3	13	Develop charter for Safety Review Panel.	1Q, 2004
3	14	Establish business practices.	2Q, 2004
4	15	Prepare draft R&D needs whitepaper.	4Q, 2003
4	16	Finalize draft of R&D needs whitepaper.	1Q, 2004

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4	17	Assess literature survey of failure modes for areas of additional study and research.	3Q, 2004
4	18	Input from Education: Public perceptions assessment	4Q, 2004
4	19	Input from Education: Public perceptions assessment	4Q, 2007
4	20	Input from Education: Public perceptions assessment	4Q, 2010
5	21	Gather and review data to support the inclusion of hydrogen safety in procurements.	4Q, 2003
5	22	Present procurement request to general counsel.	4Q, 2003
5	23	Finalize terms and conditions for DOE procurements that include safety reviews.	2Q, 2004
6	24	Convene a meeting of Hydrogen Safety Review Panel.	1Q, 2004
6	25	Output to Production: Safety requirements and protocols for refueling	2Q, 2004
6	26	Draft criteria and procurement plan.	3Q, 2004
6	27	Present procurement plan to the contracting officer (and project engineer for concurrence).	4Q, 2004
6	28	Output to Delivery: Safety requirements and protocols for pipelines and transit	2Q, 2005
6	29	Output to Education: Training materials for testing and certification for engineered systems	2Q, 2005
7	30	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2004
7	31	Establish annual review criteria for safety.	2Q, 2005
7	32	Conduct review of projects.	3Q, 2005
7	33	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2005
7	34	Conduct review of projects.	3Q, 2006
7	35	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2006
7	36	Conduct review of projects.	3Q, 2007
7	37	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2007
7	38	Conduct review of projects.	3Q, 2008
7	39	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2008
7	40	Conduct review of projects.	3Q, 2009
7	41	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2009
7	42	Conduct review of projects.	3Q, 2010

7	43	Incorporate programmatic review comments into Safety Review Panel's business practices.	4Q, 2010
8	44	Develop format for accessibility and use.	3Q, 2005
8	45	Establish reporting criteria for all collected data.	3Q, 2005
8	46	Inventory existing data with industry and government for adequacy and quality.	3Q, 2006
8	47	Populate the database.	4Q, 2006
9	48	Review existing safety protocols.	4Q, 2005
9	49	Develop reporting format for validation projects.	1Q, 2006
9	50	Develop reporting format for R&D projects.	2Q, 2006
9	51	Establish priorities for safety assessments.	2Q, 2006
9	52	Complete assessments for high-priority projects.	4Q, 2008
10	53	Assemble team to prepare Best Management Practices Handbook.	4Q, 2009
10	54	Complete draft of Handbook.	2Q, 2010
10	55	Complete final peer-reviewed Handbook.	4Q, 2010

Table B.8. Education Milestones

Task	Milestone	Description	Date (FY)
1	1	Complete website needs assessment.	4Q, 2003
1	2	Complete "phase 2" website upgrades and improvements ("phase 1" was initial launch, completed January 28, 2003).	2Q, 2004
1,2	3	Input from Codes & Standards: Training modules for current practices	2Q, 2004
1,2	4	Deliverable: Create library of materials, including, but not limited to the following: fuel cell technology fact sheets, hydrogen "basics" fact sheet (production, storage, delivery), hydrogen safety fact sheet, technology "challenges" fact sheet	4Q, 2004
1,2	5	Input from Codes & Standards: Training modules for amended practices for new technologies	2Q, 2005
1,2	6	Input from Safety: Safety training materials for testing and certification for engineered systems	2Q, 2005
1,2	7	Deliverable: Publish safety training materials	3Q, 2005
1,2	8	Deliverable: Publish Codes and Standards modules	3Q, 2005
1,2	9	Input from Technology Validation: Final report for first generation vehicles, interim progress report for second generation vehicles on performance, safety, and O&M	1Q, 2007

1,2	10	Deliverable: Publish data from first generation Technology Validation projects	2Q, 2007
1,2	11	Input from Technology Validation: Issue final report on vehicle performance, safety, and O&M	3Q, 2010
1,2	12	Deliverable: Publish data from second generation Technology Validation projects	4Q, 2010
2	13	Identify opportunities to tie into existing clearinghouse infrastructures.	4Q, 2003
2	14	Establish information clearinghouse.	2Q, 2004
3	15	Identify and review existing teaching materials for grades K-12.	2Q, 2004
3	16	Identify partners and develop detailed plan for coordinated materials development/teacher training program.	2Q, 2004
3	17	Identify and evaluate opportunities to work with traditional textbook companies to incorporate hydrogen and fuel cell information.	3Q, 2004
3	18	Launch materials development component of secondary school education program in conjunction with pilot teacher training/professional development program for secondary school teachers.	3Q, 2005
3	19	Deliverable: Publish secondary school teaching tools	1Q, 2006
3	20	Complete comprehensive training of an additional 50-100 secondary school teachers and revise program, as appropriate.	3Q, 2006
3	21	Complete training of 500-1,000 secondary school teachers.	3Q, 2007
3	22	Expand/adapt teacher training program to elementary schools	3Q, 2008
3	23	Deliverable: Publish elementary school teaching tools	1Q, 2009
3	24	Complete comprehensive training of 50-100 elementary school teachers and revise program as appropriate.	3Q, 2009
4	25	Deliverable: Publish database of existing university programs	3Q, 2004
5	26	Expand hydrogen and fuel cell focus of current DOE-sponsored university programs.	4Q, 2004
6	27	Establish baseline level of public awareness and perceptions.	4Q, 2004
6	28	Output to Safety: Publish initial perceptions report	4Q, 2004
6	29	Conduct follow-up public perception analysis.	4Q, 2007
6	30	Output to Safety: Publish interim perceptions report	4Q, 2007
6	31	Complete public perception assessment and results analysis.	4Q, 2010
6	32	Output to Safety: Publish perceptions report	4Q, 2010
7	33	Identify audience needs and complete initial list of industry and other partners for public education campaign.	4Q, 2007
7	34	Create detailed plan for full-scale public education campaign.	2Q, 2008

7	35	Develop and test key messages for public education campaign and identify effective communication mechanisms.	3Q, 2008
7	36	Pilot public education campaign strategies in communities with ongoing technology validation activities.	1Q, 2009
7	37	[1]Go-Now/Go-Later: Decision point on launch of full-scale public education campaign	1Q, 2010
8	38	Complete assessment of opportunities for joint education activities with existing community partnership programs.	1Q, 2004
8	39	Implement strategies to coordinate education activities with state and local partners and facilitate information sharing among partners.	2Q, 2004
8	40	Identify partners to serve on Hydrogen Education Review Panel	1Q, 2005
8	41	Launch Hydrogen Education Review Panel	4Q, 2005
9	42	Establish a coordination plan with Codes and Standards and Safety program elements to run workshops for state and local officials	3Q, 2004

[1]Timing for the launch of a full-scale public education campaign depends on the status of the technology and whether there is a clear call to action

Appendix C – Benefits Assumptions

This appendix has been added for the reader who would desire additional information that could be provided in the Program Benefits section of the Hydrogen, Fuel Cells, and Infrastructure Technologies Program RD&D Plan.

References

T.S. Ahlbrandt, R.R. Charpentier, T.R. Klett, J.W. Schmoker and C.J. Schenk in Analysis of Results Chapter from the U.S. Geological Survey Digital Data Series 60 U.S. Geological Survey World Petroleum Assessment 2000 – Description and Results and U.S Geological Survey Digital Data Series –DDS-60, USGS World Energy Assessment Team, U.S. Department of the Interior, U.S. Geological Survey, http://greenwood.cr.usgs.gov/energy/WorldEnergy/DDS-60/ .

(1) U.S. vehicles: "*Highway Statistics Summary to 1995, Table MV-20*0" and "*Highway Statistics 1997-2001,* annual, *Table VM-1,"* Office of Highway Policy Information, Federal Highway Administration, U.S. Department of Transportation; (2) International vehicles: "Ward's World Motor Vehicle Data," Ward's Communications, Southfield MI; (3) International Population: *World Population Profile, 1998* , U.S. Census Bureau, Washington, DC.; (4) U.S. Population: Historical Population Estimates: 1900-1999, Population Division, U.S. Census Bureau, Washington, DC.

Davis, Stacy C. and Susan W. Diegel, Transportation Energy Data Book, Edition 22, Oak Ridge National Laboratory, September 2002

The total fuel cycle analysis including the environmental analysis was conducted using the GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model, developed by the Center for Transportation Research at Argonne National Laboratory for the U.S. Department of Energy. A more comprehensive review of fuel cycle issues for fuel cell vehicles is included in "Fuel Choices for Fuel-Cell Vehicles: Well-to-Wheels Energy and Emission Impacts," by Michael Wang (ANL) published in Journal of Power Sources, Volume 112 (2002): pp. 307-321.

Contribution of the Automotive Industry to the U.S. Economy in 1998, prepared by the University of Michigan and the Center for Automotive Research, Winter 2001

(1) Historical Transportation Oil Consumption by Mode: Davis, SC and S.W. Diegel, "Transportation Energy Data Book: Edition 22," Oak Ridge National Laboratory Report ORNL-6967, Oak Ridge, TN; (2) Transportation Oil Consumption by Mode to 2025: "Annual Energy Outlook With Projections to 2025: Table 7 from Detailed Tables Generated by NEMS-FTab," Energy Information Administration, U.S. Department of Energy Report DOE/EIA-0383(2003), Washington, DC.; (3) Transportation Oil Consumption 2026-2040: AEO 2003 projections extended by using the average annual growth rate during 2020-2025.; (4) Oil Savings from Light Duty Vehicles with Fuel Cells: From a VISION Model (developed at Argonne National Laboratory for DOE) run documented in the appendix to this section.

Modeling of the Oil Savings Benefit from Fuel Cell Vehicles

The recently announced Presidential hydrogen fuel initiative states that light duty fuel cell vehicles (FCVs) could save over 11 mmb/d oil by 2040. This reduction in oil demand is relative to the oil that light duty conventional vehicles (CVs) might otherwise consume in 2040. The estimate was developed using the VISION model. This model was developed by DOE to provide estimates of the potential energy use, oil use and carbon emission impacts through 2050 of advanced light- and heavy-duty highway vehicle technologies and alternative fuels. VISION was used instead of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) in part because NEMS only provides such estimates to 2025. Further, NEMS market penetration estimates themselves require projections of fuel prices, vehicle costs, and vehicle attributes. The prediction of fuel prices beyond 2025 is extremely uncertain, while predictions of H2 FCV vehicle cost and attributes would be premature this early in the program, since yet to be discovered technical and cost breakthroughs are the goal of the program.

The VISION model consists of two Excel workbooks: one a Base Case of US highway fuel use and carbon emissions to 2050 and another a copy of the Base Case which can be modified to reflect alternative assumptions about advanced vehicle and alternative fuel market penetration. Oil savings estimates that are derived using this model are thus based on a number of assumptions about advanced vehicle (e.g., FCV) penetration, energy efficiency and resource fuel as well as assumptions about Base Case vehicle oil use which in turn is dependent on vehicle fuel, efficiency and travel.

A number of key modeling assumptions lead to the oil savings estimate calculated. They are as follows:

1) VISION uses EIA projections as much as possible in its Base Case. At this time, VISION uses the projections contained in EIA's Annual Energy Outlook (AEO) 2002. EIA has subsequently released AEO 2003 that actually implies higher oil use by light-duty vehicles (LDVs). VISION is being updated to incorporate these latter estimates, but the VISION results discussed here are based on AEO 2002 estimates.

2) The certification test fuel economy of new gasoline-fueled CVs in the Base Case is fixed at 28.5 MPG for cars and 21.2 MPG for light trucks throughout the analysis period. This assumption differs from EIA's latest projections of slight improvements in the fuel economy of gasoline-fueled CVs. In AEO 2003 EIA projects an 8% increase (total) in new gasoline light truck mpg between 2002 and 2025 and a 4% increase for new gasoline cars. VISION uses a fixed MPG Base Case because many analyses want to evaluate the effects of new technology penetration relative to existing technology.

3) All of the CVs in the Base Case are gasoline-fueled. Again this differs from EIA's AEO 2003 projections. By 2025, EIA projects that 17% of all LDVs sold in that year will be in a category defined by EIA as alternative fuel vehicles (AFVs). Though present hybrid electric vehicles run on gasoline and most, if not all, future hybrid electric vehicles will likely also run on gasoline, EIA nevertheless includes hybrid vehicles in its accounting of AFVs. Over 90% of EIA's AFVs will be hybrid electric and ethanol flex fuel vehicles, both of which will or can use gasoline (or diesel in the case of diesel hybrids). Only 0.04% would be FCVs. Again, the Base Case in VISION assumes 100% gasoline CVs in the future in order to evaluate the effects of new technology penetration relative to the predominant existing technology.

4) VISION includes Class 2b trucks (8,500 –10,000 lbs GVW) in its estimates of LDV fuel use. EIA does not.

5) The annual VMT per LDV in VISION is based on EIA's AEO 2002 vehicle-miles traveled (VMT) estimates extended to 2050. In VISION, average LDV VMT rises from 12,200 in 2002 to 13,859 in 2020, then to 14,737 in 2040, and finally to 15,000 by 2050. Cars and light trucks are used differently but by 2030 their average annual VMT is quite similar. EIA's AEO 2003 VMT estimates differ from its AEO 2002 estimates.

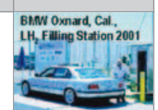
6) The energy efficiency of FCVs relative to current technology CVs is substantial, but also much debated. A future FCV is likely to be two to three times as energy efficient as a current technology CV. In the VISION run used to develop the oil savings estimate for the FreedomCAR and Fuel Initiative, the relative energy efficiency of FCVs was assumed to a) be 2.25 in 2018 through 2020, b) increase linearly to 2.5 by 2030 and c) remain there until 2040. We assumed that a FCV's relative energy efficiency would eventually reach 3.0, but not until post-2040.

7) When FCVs might be mass marketed is not known. But in this case it is assumed that FCVs would begin to be sold in substantial numbers in 2018 and reach 52.2% of LDV sales in 2025. The specific penetration rates that were assumed are 4% in 2018, 27% in 2020, 52% in 2025, 78% in 2030 and 100% in 2038, with linear interpolation generally used for intervening years. Hydrogen supplies are assumed to be available to facilitate this market penetration level. The reasonableness of these market penetration assumptions, in a historical context, are discussed in the next section.

8) The FCVs do not use petroleum (i.e., on-board reforming of gasoline is not assumed). The H2 used by the FCVs is produced from natural gas or zero-carbon fuels.

Given the assumptions listed above, use of H2 FCVs was estimated with the VISION model to generate an 11 mmb/d savings in oil consumption in the light-duty transportation sector in 2040 (11.6 mmb/d to be more precise). Such a substantial savings in oil consumption would likely lead to lower oil prices than would otherwise occur. If world oil supplies are depleted within the time frame of the scenario, the hydrogen switch might be timely in preventing very high oil prices. If oil is abundant in that time frame, then energy security would be provided for the U.S., but oil might be used to a greater extent elsewhere in the world. VISION does not in any way evaluate interactions of world oil prices and oil demand.

Appendix D - Worldwide Hydrogen Fueling Stations

Location	Fuel	Project	Dates	H2 Production Technique	Specifics/ Comments	Picture
Davis, California	Compressed H2	University of California-Davis Hydrogen Bus Technology Validation Program	In operation	Air Products delivered LH2	N/a	N/a
El Segundo, California	Compressed H2	Xerox Corp., DOE, UC Riverside, Matrix Engineers, City of West Hollywood, Kaiser Engineering, SCAQMD, CAN	Opened in 1995	Praxair fueling system; PVI Corp. photovoltaics; Stuart Energy hydrogen fueling station: electrolyzer	Electrolytic H2 generation "Clean Air Now Solar Hydrogen Vehicle Project"	
Thousand Palms, California	Compressed H2	SunLine Transit Agency and Ballard P4 Bus Demo.	Opened April 2000	Stuart Energy hydrogen fueling station	Electrolytic H2 generation and compression to 34.5 Mpa; 1,400 scfh	
Sacramento, California	Liquid to Compressed H2	Ca Fuel Cell Partnership BP, Shell, and Texaco helped in the design	Opened November 2000	Air Products and Praxair delivered LH2	LH2 Stored on site in 4500-gallon tank. Can deliver CH2 to vehicle at 3600 and 5000 psi under 4 min	
Torrance, California	Compressed H2	American Honda Motors Co., Inc., Research and Development center	Opened July 20, 2001	N/a	PV-electrolysis with grid electricity back-up	
Torrance, California	Compressed H2	As part of Toyota's efforts to establish California fuel cell "communities" with the leasing of 6 FCHVs to 2 UC campuses, it plans to open 5 more refueling stations in addition to this one by mid-2003	Opened early 2003	Toyota will work with Stuart Energy and Air Products and Chemicals, Inc.	Toyota USA headquarters in Torrance uses a Stuart Energy hydrogen fueling station. It uses on-site electrolysis powered by renewable energy to generate 24 kg hydrogen/ day.	
Oxnard, California	Liquid H2	BMW North America Engineering and Emission Test Center	Opened July 12, 2001	Air Products delivered LH2	Manual power-assisted refueling station	
Chula Vista, California (mobile station)	Compressed H2	City of Chula Vista	To be delivered early 2003	Stuart Energy hydrogen fueling station	A CFP-1350 generates 60 kg of H2/day, can fuel 3 buses a day, and dispenses at 3,600 and 5,000 psi.	
Thousand Palms, California	Compressed H2	Schatz Hydrogen Generation Center at SunLine Transit	Opened 1994; retro-fit in 2001 – 02	Teledyne Energy electrolyzer System	3600-psi hydrogen generation via electrolysis powered by renewable PV; produces up to 42 scfh of H2	
Richmond, California	Compressed H2	AC Transit facility	Opened Oct. 30, 2002	Stuart Energy hydrogen fueling station	"Intelligent" hydrogen fueling station, using PEM electrolyzer: first satellite hub for CaFCP vehicles. Has 47 kg H2 storage capability.	
San Jose, California	To Be Determined (TBD)	VTA, San Mateo Transportation District, CaFCP, and CARB	2004 readiness target	Air Products delivered LH2	Current fueling station at VTA's San Jose division will be enhanced with hydrogen capabilities	N/a
Chicago, Illinois	Liquid to Compressed H2 at station	Chicago Transit Authority – Ballard Bus Demo.	03/98 – 02/2000	Air Products delivered LH2	N/a	
Dearborn, Michigan	Liquid H2 and Liquid to Compressed H2 at Station	Ford Vehicle Refueling Station	Opened in 1999	Air Products and Chemicals delivered hydrogen	N/a	
Arizona (mobile station)	Compressed H2	Ford Motor Company	Delivered in 2001	Stuart Energy hydrogen fueling station – CFP-450	This is a full Stuart Energy hydrogen fueling station installed on a flatbed trailer (H2 generation, compression, storage, and dispensing). It generates 24 kg of H2 per day, stores about 47 kg, and dispenses at ~~both~~ 3,600 and 5,000 psi.	
Phoenix, Arizona	Compressed H2	Arizona Public Service and DOE Vehicle testing center – part of DOE Field Operations Program	Opened in 2001	Proton Energy's HOGEN PEMFC electrolyzer	Only DOE-/private sector H2 station	

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Northern Nevada (65 miles north of Las Vegas)	Compressed H2	Nevada Test Site Development Corp., DOE, Corporation for Solar Technologies and Renewable Resources and eCity of Las Vegas	Opened 11/15/02	Air Products and Chemicals	First multi-purpose station: H2 production via NG reformation; electricity production (for sale) using 50kW PEMFC; H2/CNG blends and pure H2 vehicle dispensers (uses Plug Power PEM fuel cell)	
Munich, Germany	Liquid H2	BMW Company Refueling Station	Opened in1989	Linde	N/a	N/a
Hamburg, Germany W.E.I.T. phase I	Compressed H2	W.E.I.T. hydrogen project Services hydrogen vehicles for: Hamburg Hermes Versand Service, HEW, and HHA	Opened on 12/01/99	Delivered Compressed H2 by m-tec Gastechnologie and Messer Griesheim	On-site electrolysis using ~~'G~~green~~'~~ electricity and 100% fuel cell powered vehicles is the current goal/direction of this project	
Hamburg, Germany W.E.I.T. phase II	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	Hamburgische Electricitätswerke AG subsidiary, GHW	On-~~-~~site hydrogen from electrolysis via renewable wind power. This is the second phase of the W.E.I.T project, which will incorporate the Hamburg CUTE project	
Nabern, Germany	Liquid H2	DaimlerChrysler Company Refueling Station	Opened in1998	N/a	N/a	N/a
Munich, Germany	Compressed H2 and Liquid H2 and Liquid to Compressed H2	Munich Airport Vehicle Project Bavaria's minister for economics, transportation and technology	05/99 – 2001	Hamburgische Electricitätswerke AG subsidiary, GHW	MAN hydrogen ICE buses drove more than 280,000 km w/out any breakdowns. Publicly Accessible	
Wolfsburg, Germany	Liquid H2	On-site fueling for VW hydrogen vehicles	N/a	N/a	N/a	N/a
Russelsheim, Germany	Liquid H2	On-site fueling for Opel hydrogen vehicles	N/a	N/a	N/a	N/a
Sindelfingen, Germany	Compressed H2 and Liquid H2	DaimlerChrysler	planned	N/a	35 Mpa	N/a
Berlin, Germany	H2 and Liquid Hydrogen and Conventional fuels	Aral, BMW, BVG, DaimlerChrysler, Ford, GHW, Linde, MAN and Opel: Clean Energy Partnership (CEP)	2003 target	The Aral station will use Linde H2 supplied hydrogen	World's ~~1st~~ first public hydrogen gas station	
Berlin, Germany	Liquid and Compressed Hydrogen	TotalFinaElf, BVG, Linde, MAN and Opel: Hydrogen Competence Center Berlin. Station was opened under the framework of the Berlin, Copenhagen, Lisbon fuel cell bus Program	Opened 10/23/02	Will use Linde supplied liquid hydrogen and Proton Energy Systems' HOGEN® PEM electrolyzer for Compress. H2	~~1st~~ First permanent hydrogen fuel station in Berlin; will fuel H2 ICE buses from MAN and fuel cell buses Also includes a Linde AG mobile filling station	
Copenhagen	Mobile LH2	Station was opened under the framework of the Berlin, Copenhagen, Lisbon fuel cell bus Program	2002/3 target	Will use Linde supplied liquid hydrogen	The Linde mobile filling station is a part of the Total Fina Elf station in Berlin; and will be used in Copenhagen and Lisbon as part of this fuel cell bus demonstration program	
Lisbon	Mobile LH2	Station was opened under the framework of the Berlin, Copenhagen, Lisbon fuel cell bus Program	2002/3 target	Will use Arliquido (in Portugal) supplied liquid hydrogen	The Linde mobile filling station is a part of the Total Fina Elf station in Berlin; and will be used in Copenhagen and Lisbon as part of this fuel cell bus demonstration program	
Erlangen, Germany	Mobile Liquid H2	MAN, Linde (several Bavarian funded bus programs)	4/12/96 – 8/98 (ICE) and again in 10/2000 – 04/2001 (fuel cell)	Linde AG produced and supplied the LH2 to their mobile station	Linde AG supplied LH2 from ~~their~~ its large central H2 production and Liquification plant and transported it to the Linde mobile fueling station	
Oberstdorf Spa, Germany	Compressed H2	Neoplan fuel cell bus at Oberstdorf; funded by Bavarian State	1999 – 2001	Linde AG produced and supplied the LH2 to their mobile station	Linde AG supplied LH2 from ~~their~~ its large central H2 production and Liquification plant and transported it to the Linde mobile fueling station	N/a
Stuttgart, Germany	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	BP affiliated	On-site ~~N~~natural ~~G~~gas stream reformation	N/a
Stockholm, Sweden	Compressed H2	Clean Urban Transport for Europe (CUTE) Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	Stuart Energy's 'intelligent' hydrogen fueling station	Central ~~H~~hydro-~~P~~powered electrolysis, then transported to fueling site	N/a

London, United Kingdom	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	BP affiliated	Centralized production via excess hydrogen from crude oil, then transported to fueling site	N/a
Amsterdam, The Netherlands	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	Hydrogen System's IMET☒ powered water electrolyzer and Linde (Hoekloos)	On site Hhydrogen production via electrolysis from green energy	N/a
City of Luxemburg	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	N/a	On-site Mmethanol steam reformation	N/a
Oporto, Portugal	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	BP affiliate	Centralized production via excess hydrogen from crude oil	N/a
Madrid, Spain	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	N/a	Centralized production via excess hydrogen from crude oil	N/a
Barcelona, Spain	Compressed H2	CUTE Bus Demo. PLANET from EUHYFIS in charge of H2 station	2003 target	BP and Vandenborre Hydrogen Systems: IMET☒ powered water electrolyzer	On-site production via renewable solar and grid electricity powered electrolysis	N/a
Europe	Compressed H2	EU, Bauer Kompressoren, Casale Chemicals, PLANET (EUHYFIS Project)	RandD phase complet, 1st demo station in 2004	N/a	On-site electrolysis of water from a renewable electrical source (solar or wind) Currently contributing to the CUTE program	
Reykjavik, Iceland	Compressed H2	ECTOS Bus Demo.	2003 target	Shell Hydrogen/Iceland	On-site gGeothermal- and Hhydro--Ppowered eElectrolyzer	N/a
Perth, Australia	Compressed H2	DaimlerChrysler, BP, UNEP Similar to the CUTE program	2004 target	Centrally produced H2 at BP's refinery in Kwinana	This is a 'least-cost' solution for the purposes of the trial only. In the long term the intention is to use steam reformation of natural gas for H2 production	N/a
Victoria, Australia	Compressed H2	One H2 fueling station to service several hydrogen fuel cell buses taking passengers to and from the Victorian Fast Train (program is under review)	TBD	TBD	Reviewing electrolysis via solar and reforming natural gas	N/a
Beijing, China	To be determined (TBD)	Global Environment Facility (GEF) and United Nations Development Program (UNDP): commercial demonstrations of 6 fuel cell buses and hydrogen refueling stations.	2003 target	N/a	N/a	N/a
Shanghai, China	TBD	Global Environment Facility (GEF) and United Nations Development Program (UNDP)	2003 target	N/a	N/a	N/a
Cairo, Egypt	TBD	Global Environment Facility (GEF) and United Nations Development Program (UNDP)	2003 target	N/a	N/a	N/a
Mexico City, Mexico	TBD	Global Environment Facility (GEF) and United Nations Development Program (UNDP)	2003 target	N/a	N/a	N/a
New Delhi, India	TBD	Global Environment Facility (GEF) and United Nations Development Program (UNDP)	2003 target	N/a	N/a	N/a
Sao Paulo, Brazil	TBD	Global Environment Facility (GEF) and United Nations Development Program (UNDP)	2003 target	N/a	N/a	N/a
Osaka, Japan	Compressed H2	PEMFC Vehicle Demo. by WE-NET	Fall 2001 – end of 2003	N/a	Natural gGas rReforming	
Takamatsu, Japan	Compressed H2	PEMFC Vehicle Demo. by WE-NET	Fall 2001 – end of 2003	N/a	PEM electrolyzer	
Tsurumi, Japan	Compressed H2	PEMFC Vehicle Demo. by WE-NET	Opened Aug. 2002	N/a	N/a	N/a

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Yokohama, Japan	Compressed H2	Cosmo Oil JHFC	Opened FY2002	N/a	Part of Japan Hydrogen and Fuel Cell Demonstration Project, which will build 5 H2 stations in Tokyo Desulfurized-gasoline ~~r~~Reformation	N/a
Yokohama, Japan	Compressed H2	Nippon Oil JHFC	Opened FY2002	N/a	Part of Japan Hydrogen and Fuel Cell Demonstration Project, which will build 5 H2 stations in Tokyo Naphtha Reformation	N/a
Japan	Compressed H2	Company Filling Stations for Honda	Opened in 2001	N/a	N/a	N/a
Japan	Compressed H2	Company Filling Station at Toyota	Opened in 2001	N/a	N/a	N/a
Tokai, Japan	Compressed H2	Toho Gas Co. owned. Will sell the hydrogen fuel at a price similar to gasoline	Opened 10/2002	N/a	Located at Toho Gas Co.'s research laboratory in Aichi Prefecture	N/a
Tokyo, Japan	Liquid H2 and Compressed H2	Iwatani International Corporation; Tokyo Metropolitan Government, Showa Shell Sekiyu KK JHFC	Target: April 2003 – 2 year operation	Shell Hydrogen technological know how	Tokyo's first hydrogen station Part of Japan Hydrogen and Fuel Cell Demonstration Project, which will build 5 H2 stations in Tokyo	N/a
Kawasaki City, Japan	Compressed H2	Air Liquide Japan JHFC	FY 2003 target	N/a	Part of Japan Hydrogen and Fuel Cell Demonstration Project, which will build 5 H2 stations in Tokyo Methanol ~~r~~Reformation	N/a
Tokyo, Japan	Compressed H2	Tokyo Gas and Nippon Sanso JHFC	N/A	Senju	Part of Japan Hydrogen and Fuel Cell Demonstration Project, which will build 5 H2 stations in Tokyo LPG reforming	N/a
Vancouver, Canada	Compressed H2 and H2/Natural Gas blend	British Columbia Hydro's Powertech Labs	Opened in 2001	Stuart Energy hydrogen fueling station: electrolyzer	Used for Coast Mountain Transit's fuel cell bus demonstration from '98-00. It now supplies H2 as well as a blend of H2/Natural Gas to a variety of vehicles.	
Montreal, Canada	Compressed H2	Montreal Urban Transit Authority	Opened and Closed in 1994	Stuart Energy hydrogen fueling station: electrolyzer	Electrolytic H2 generation and compression to 34.5 Mpa; 1,400 standard cubic feet per hour	N/a
Surrey, BC Canada	Compressed H2	BC HydroGen	Opened Fall of 2001	N/a	70 Mpa hydrogen via electrolysis from renewable energy	N/a
Torino, northern Italy	Compressed H2	Irisbus PEMFC City Bus Demo.	2002/3 target	N/a	Hydrogen from hydropower via electrolysis	N/a
Bi-cocca (near Milano)	Compressed H2 and Liquid H2	Hydrogen and fuel cell demonstration project	Opened in 2002	AEM, SOL, and others	Hydrogen liquefier and vehicle refueling	N/a
Oostmalle, Belgian	Liquid H2	Belgian Bus Demo.	Opened in1994	Messer Griesheim GmbH	LH_2 storage system of 125 L, an electric LH_2 evaporation system as well as all necessary connecting supply infrastructure and relevant control and safety components	N/a
Leuven, Belgium	Compressed H2	NexBen Fueling—a division of Chart—has won a contract from Citensy	2003	NexBen Fueling	Europe's first combined liquefied natural gas (LNG) and liquid compressed natural gas (LCNG) and hydrogen fueling station "First of Many"	
South Korea	Compressed H2	Hyundai Motor Company fuel cell vehicle research	Opened in 2001	Pressure Products Industries, Inc. and Doojin Corporation	The heart of the fueling station is a PPI two stage compressor, model 4V104068 designed for 6,000 psig	N/a
Submarine – mobile infrastructure		Class 212 submarine: driven by hydrogen fuel cells dependent on outer air.	Finished in 2002	Air Products (USA)	World's ~~1st~~ first installed complete hydrogen infrastructure in a non-nuclear hydrogen driven submarine.	

Appendix E–2003 DOE Hydrogen, Fuel Cells, & Infrastructure Technologies Program Review Meeting

Project Evaluation Form

SESSION: **TITLE:** **Project # _______**
PRESENTER: **ORGANIZATION:**
REVIEWER NAME:

Using the following criteria, please rate the **work** presented in the context of program objectives. Please provide **specific** comments to support your evaluation. Note: These evaluation criteria have been modified to more closely reflect the Office of Management and Budget's scoring criteria for applied R&D investments.

1. Relevance to overall DOE objectives. The degree to which the project supports the President's Hydrogen Fuel Initiative and the goals and objectives in the EERE Hydrogen, Fuel Cells, and Infrastructure Technologies Program R, D, and D plan.

4 - Outstanding. The project is critical to realization of the President's hydrogen vision and fully supports the objectives of the R, D, & D plan.		Specific Comments:
3 - Good. Most aspects of the project align with the President's Hydrogen Fuel Initiative and R, D, & D Plan objectives.		
2 - Fair. The project partly supports the President's Hydrogen Fuel Initiative and the R, D, & D Plan objectives.		
1 - Poor. The project provides little support to the President's Hydrogen Fuel Initiative and the R, D, & D Plan objectives.		

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2. **Approach** to performing the research and development. The degree to which market barriers are addressed. The degree to which the project is well-designed, integrated with other research, and technically feasible.

4 - Outstanding. The project is sharply focused on one or more key technical barriers to development of hydrogen or fuel cell technologies. It is well integrated and it is difficult for the approach to be improved significantly.		Specific Comments:
3 - Good. The approach is generally well thought out and effective, but could be improved in a few areas. Most aspects of the project will contri≠bute to significant progress in over≠coming these barriers. Some integration with other research apparent.		
2 - Fair. Some aspects of the project may lead to progress in overcoming some barriers but the approach has significant weaknesses.		
1 - Poor. The approach is not responsive to the project objectives and unlikely to make signi≠fi≠cant contributions to overcoming the barriers.		

3. Technical Accomplishments and Progress toward project and DOE goals. The degree to which research progress is measured against performance indicators. The degree to which the project elicits improved performance (effectiveness, efficiency, and benefits.)

4 - Outstanding. The project has made excel≠lent progress toward overcoming one or more key technical barriers to develop≠ment of auto≠motive fuel cells as evidenced by progress measured against performance indicators; progress to date suggests that the barrier(s) will be over≠come.		Specific Comments:
3 - Good. The project has shown significant progress toward overcoming barriers as demonstrated against performance indicators.		
2 - Fair. The project has shown a modest amount of progress in overcoming barriers, and the overall rate of progress has been slow.		
1 - Poor. The project has demonstrated little or no progress toward overcoming the barriers.		

4. Technology Transfer/Collaborations with Industry/Universities/Other Laboratories

4 - Outstanding. Close coordination with other institutions is in place; industrial partners are full participants.		Specific Comments:
3 - Good. Some coordination exists; full coor≠dination could be accomplished fairly quickly.		
2 - Fair. Some coordination exists; full coordination would take significant time and effort to initiate.		
1 - Poor. Most or all of the work is done at the Lab with little outside interaction.		

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5. Approach to and Relevance of **Proposed Future Research.** The degree to which the project plan has off-ramps, i.e., decision points where the project could be ended.

4 - Outstanding. Future work plan builds on past progress and is sharply focused on one or more key technical barriers to develop≠ment of automotive fuel cells in a timely manner. Upcoming decisions and project end points are clearly defined.		Specific Comments:
3 - Good. Future work plan builds on past progress and generally addresses removing or diminishing barriers in a reasonable timeframe. Decisions points defined.		
2 - Fair. Future work plan may lead to improvements, but should be better focused on removing or diminishing key barriers within a reasonable time period.		
1 - Poor. Future work plan has little rele≠vance or benefit toward eliminating≠ barriers.		

Specific **Strengths and Weaknesses**

Specific **Recommendations/Additions or deletions to the work scope**